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MINE WARFARE IN NWGS

by

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MINE WARFARE IN NWGS

1. Preface

The acceptance of NWGS by the Navy will initiate a period where some of the PL/I procedures are changed to become more realistic or faster or maybe both. It is my hope to participate in this, both through funded research and through theses. However, there is an important obstacle that might as well be recognized at the outset: it is going to be impossible, or at least very difficult, for NPS to write, debug, and test the PL/I code that is the natural end product of such activity. There are several reasons for my speculation:

1. NPS doesn't currently have the required pair of NWGS terminals.
2. Even if NPS did have the required terminals, there is a great deal of difference between being able to participate in playing the current "official" version of NWGS (which is easy) and being able to create "unofficial" versions (which is hard, but basically what we researchers want to do).
3. PL/I is available on the NPS computer, but I bet that there are reasons why PL/I on a Honeywell computer is not the same as PL/I on IBM computer, random number generation being one of them.
4. There is such a thing as programming style. It affects naming and calling conventions, and helps in debugging and in making code more or less readable. It is much easier to preserve that style if all PL/I code is written in one place.

None of the above problems is insurmountable, and they may all be unimportant in the long run. Nonetheless, we might as well face the fact that output from NPS, at least in the short run, cannot be PL/I code that can be plugged directly into NWGS. Then what should it be? The natural response is that NPS should propose the logical model, then "somebody else" should do the coding. That may work in some cases. However, having looked at and partially understood the large amount of mine warfare code that currently exists in NWGS, I am impressed that step 2 of the above process is a major task the difficulty of which may be affected by step 1. I am also impressed that COMMINWARCOM may have some useful inputs about realism. I therefore see the desirability for early feedback about the logical model before (if) it gets turned into PL/I, to include feedback about any perceived coding difficulties. Anticipating such feedback, I have deliberately made the rest of this report only the skeleton of a mine warfare module for NWGS. I hope to participate in the fleshing out of that skeleton once "somebody else" (a PL/I programmer) is identified.

2. MWII vs. MWI

Let us agree to call the current CSC supplied mine warfare model MWI, and the proposed model MWII. MWII differs from MWI primarily in three respects, each of which is discussed in one of the subsections that follow.

a. NWGS keeps track of each individual mine in MWII, rather than just the total number of mines in a field.

b. Minefields in MWII are essentially one dimensional, rather than two dimensional as in MWI.

c. Minesweeping is much simplified in MWII. In particular, the boundaries of the minefield are known to the minesweepers, whereas they are not in MWI.

2a. It is certainly expensive in terms of computer resources to keep track of every individual mine in a minefield, but a great deal of flexibility is achieved thereby. For example, since each mine has a unique location in

MWII, the channelization countertactic (all transitors and countermeasures are concentrated in a small part of the field) is easy to simulate faithfully. In contrast, the assumptions of MWI effectively have all remaining mines constantly redistributing themselves over the whole minefield, so that channelization is impossible. Other mine characteristics that are not necessarily common amongst all mines in a field in MWII include sensitivity, charge weight, mine count, actuation probability, turn on and extinction times, an indicator of whether the mine is still alive, etc. Given the fact that NWGS already keeps track of each individual ship, the ability to keep track of such individual mine characteristics should make it easy and natural to construct a fully configured, physically accurate simulation of mine warfare. Actuation and damage curves would not be required as inputs.

2b. The one dimensional feature of MWII is an attempt to ease the computational burden associated with having to test each mine in a minefield to simulate a single transit. The idea is that mine warfare is <u>essentially</u> the business of constructing barriers that make it risky to travel from one unmined area to another. Therefore, for most purposes NWGS can think of a minefield as a line segment that cannot be crossed without risk. There are some difficulties with this argument, minesweeping being a major one, so MWII retains some two dimensional features. Nonetheless, the fundamental interaction of transitor with minefield occurs instantly and completely in MWII when the transitor's track crosses a certain crucial line segment. There are major computational advantages in this abstraction, since each mine/ship interaction needs to be considered only once per transit, and also because it is not necessary to ask mathematical questions of the form "is a point in a set?" There is also some loss of realism (fratricide, for

for example, cannot be discussed in one dimension), but the balance seems to favor the abstraction.

2c. Most theoretical work on mine warfare makes the assumption, explicitly or implicitly, that minesweeping is a "batch" activity; that is, the minesweepers decide how much and where and what kind of minesweeping to do, and then stick to the plan regardless of intermediate results. In reality, minesweeping must be essentially interactive, since even the boundaries of the minefield (not to mention mine type, etc.) must be inferred from results achieved so far. One of the potentially attractive features of MWI is that it simulates the interactive nature of minesweeping; the minesweepers are not told the exact boundaries of the minefield, and MWI's logic is prepared for the possibility that minesweeping may be partially in the wrong place. This feature could be attractive for purposes of learning about minesweeping, provided that the feedback to the minesweepers about minesweeping results is realistic. Realistic feedback is a requirement: the feature is pointless unless the "fog of war" as presented to the minesweepers is neither too thick nor too thin. The fog is too thick in the current version of MWI, since no information at all on minesweeping results is provided to the sweepers. Providing the number of mines swept as feedback would be a minor software change, but it is not possible to provide the crucial <u>locations</u> of the swept mines in a system that does not store individual mine locations in the first place.

I feel that simulation of the interactive nature of minesweping is a difficult task that simply isn't worth the trouble in a war gaming system on the scale of NWGS, and minesweeping is therefore still an essentially "batch" operation in MWII. Specifically, MWII would handle the issue by revealing the exact boundaries of the minefield to the owner of any ship that causes a detonation, by not permitting any minesweepers to be assigned to the minefield until such a detonation occurs (or until a referee intervenes), and by displaying the total number of detonations to the owner of the ships/minesweepers that have caused them. One could argue for more feedback, since there is information about detonations other than the mere fact of their occurrence that is of interest to minesweepers. In any case, however, MWII would not portray minesweeping as the subtle problem that it actually is.

3. Specific features of MWII

A minefield is created by specifying two line segments with shoreline end points, with the minefield being the region in between. As soon as the minefield is created, NWGS calculates and displays a "mine line" ML by connecting the midpoints of the sides. All mine interactions will take place on ML (see figure 1). Minefields may overlie one another.

When a minelayer that has been assigned to the minefield crosses ML, whatever mines have been assigned to the minefield are instantly delivered to uniformly random places on ML and remembered by NWGS, together with appropriate properties of each mine. Actually, the track of a minelayer that has been assigned to the field cannot cross ML; instead, the minelayer's track is reflected from ML in the direction from which it has just come, and the owner is informed that minelaying is complete (see figure 1). A "minelayer" is any ship that has been assigned to lay mines in the minefield, and is immune to the effects of the minefield when so engaged. The reflection rule is designed to prevent crossing ML safely by simply declaring oneself to be a minelayer for the minefield. Mine layers are treated like other ships when crossing minelines to which they have not been assigned. When the minefield is laid, NWGS randomly orders the mines in it, and always considers the mines in that order when transitors attempt to cross the line. This feature is meant to simulate the order usually imposed by minefield depth, and could be extended to consider the mines in reverse order for transitors approaching from the other side of ML.

When the track of any ship that has not been declared to be laying mines in the field crosses ML, the ship involved is subject to the action of the mines. For purposes of actuation/damage calculations, the crossing point is first "perturbed" by a navigation error. The random number required is selected only once per crossing; i.e., the minefield is fully configured. For each mine, a miss distance is computed by comparing the mine's position with the perturbed track. Based on that miss distance, the mine may or may not activate (see Section 4). If it detonates, it is deleted from the minefield and damage to the ship assessed. The mines are examined in order until either the ship has been sunk or all mines have been tested.

No minesweeping is possible unless the location of the minefield has been disclosed to the owner of the sweeper. To initiate sweeping, a player specifies a point on each of the outer line segments (see figure 2). NWGS then draws a "channel line" CL between the two specified points. When any ship that has been designated to be a sweeper for the minefield crosses either of the outer segments, NWGS takes over and steers the sweeper first to the appropriate endpoint of CL and then back and forth on CL. A sweeper is treated exactly like any other ship when it crosses ML or any other mine line (recall that minefields can overlie one another), except that the damage subroutine takes account of its sweeper status. When the ship is taken out of sweeper status, the player doing so also resumes responsibility for its motion.

The miner would like to have ML short and CL long, but in practice will have to make a tradeoff. CL can only be made long at the cost of causing ML to be partially on land, which in effect wastes some mines (NWGS does not truncate ML to be only the wet part). This device for forcing a tradeoff between width and depth is admittedly artificial, but the necessity for making such a tradeoff is real.

4. Activation, detonation and damage

The test for activation is $M/R^{\alpha} > S$, where M is a "strength" for the transitor, R is the horizontal miss distance on ML, α is an attenuation constant, and S is a mine sensitivity. For example, M might be a magnetic moment that NWGS computes from the displacement of the transitor and other geographic quantities, α might be 3 (the inverse cube law of magnetism), and S might be the magnetic sensitivity of the mine. Depending on the mine type, M, α, and S might have different meanings, or several tests might be performed before an actuation is counted. When the last actuation is counted, the mine detonates. Damage is handled using the existing software in NWGS. Depending on damage, the transitor may or may not continue through the minefield.

It may be wise to incorporate randomness in the selection of M for each transitor or S for each mine. The permanent moments of ships, for example, are not a perfectly predictable function of displacement, and the sensitivity of a mine may depend on its orientation. One of the delightful things about a <u>simulation</u> of a minefield is that the correct thing to do (sampling sensitivity only once for each mine, rather than once for each mine/transitor iteration) is also the easiest.

5. Quantification

LCDR Mike Morrell and I are currently working on an actuation model for magnetic mines of the form described in Section 4. The basic purpose of the model is to support minefield simulations that are run thousands of times in the process of minefield planning, so it will be very streamlined. It could serve as a "stub" for MWII pending further work in the area. A similar stub could be invented for the acoustic mechanism, although I'm not sure what is to be gained by attempting to play all possible activation mechanisms within NWGS. Pressure mines would be very hard to simulate because of their sensitivity to false activations and especially because NWGS does not currently keep track of water depth.

Minesweeping will be more difficult to quantify than simple transits, since the firing logic within the mine is more intimately involved. It is not clear to me whether it will be satisfactory to simply treat a minesweeper as an ordinary ship with an artificially large "displacement" when engaged in minesweeping. The area needs further thought, probably by the real experts at NSWC.

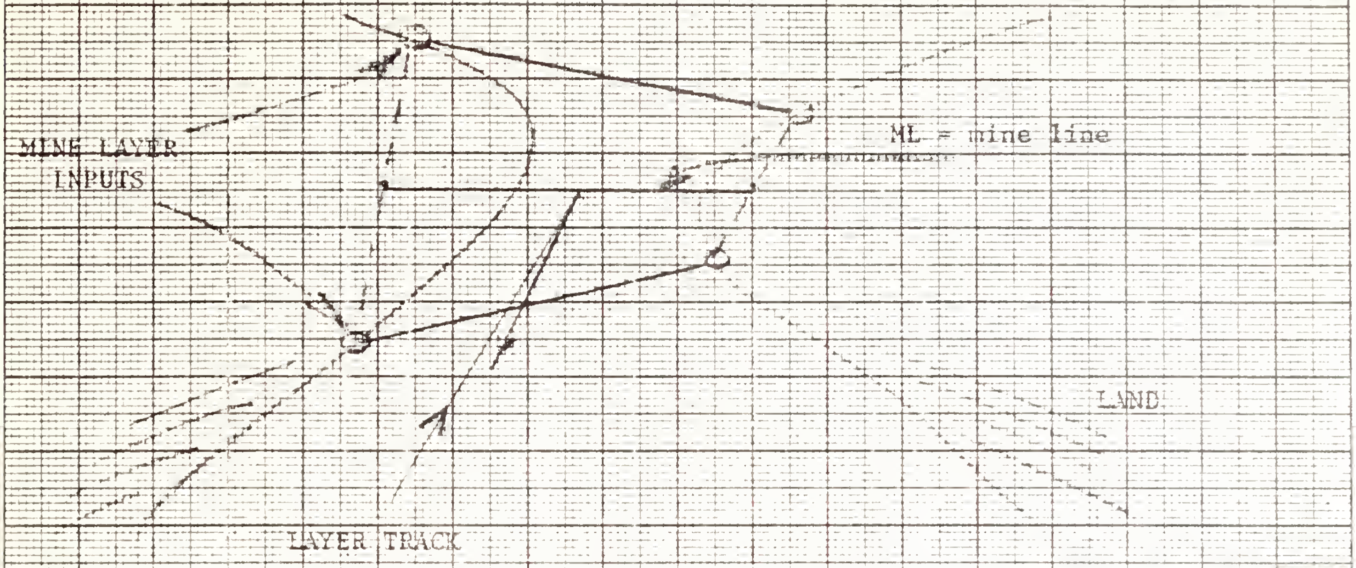

FIGURE 1

MINE LAYING IN MWII

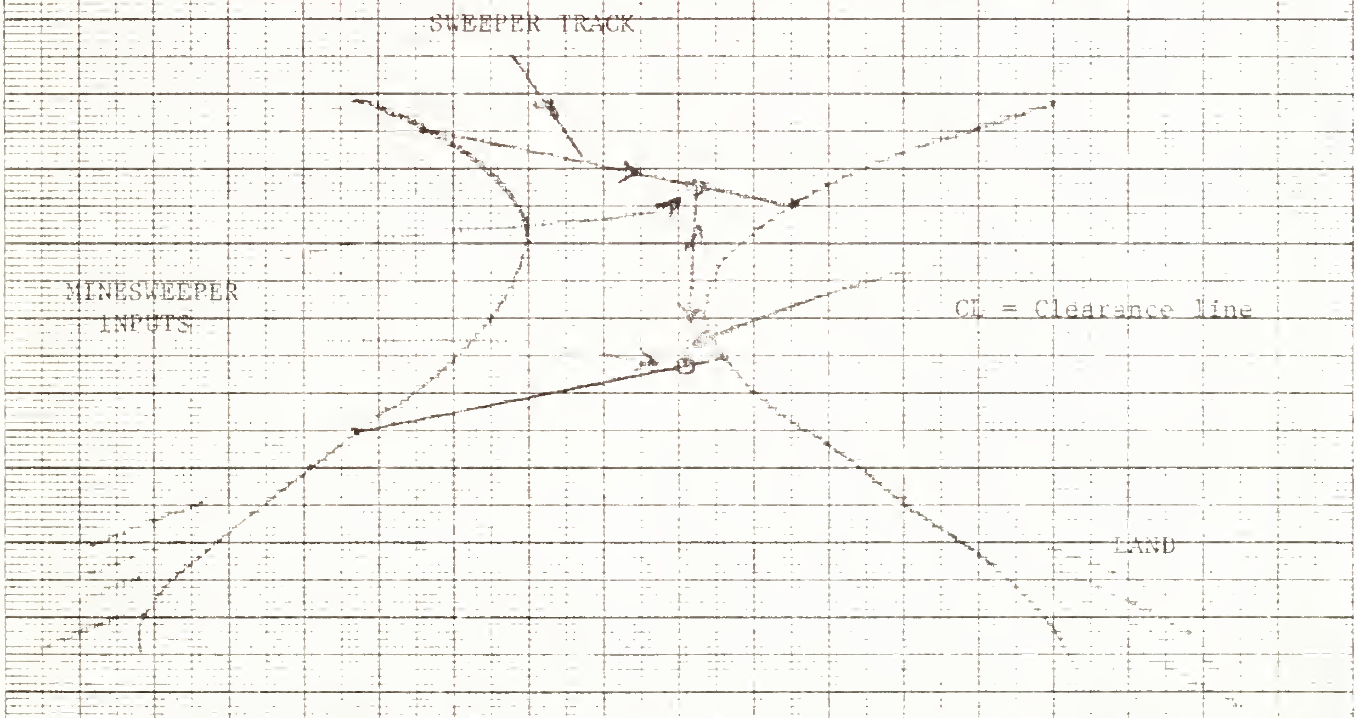

FIGURE 2

MINESWEEPING IN MWII

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